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EXPERIMENTAL INVESTIGATION OF MECHANICAL PROPERTIES OF GLASS/EPOXY LAMINATE COMPOSITES

S. RUSNÁKOVÁ[1*], D. BAKOŠOVÁ[1], J. BEZECNÝ[1], I. LETKO[1], I. RUŽIAK[2]

[1] *Department of Physical Engineering of Materials, Faculty of Industrial Technologies, Alexander Dubček University of Trenčín; Púchov, Slovak Republic, contact author: rusnakova@fpt.tnuni.sk*
[2] *Institute of Material and Technological Research, Faculty of Industrial Technologies, Alexander Dubček University of Trenčín; Púchov, Slovak Republic*

ABSTRACT: One of the primary advantages of using fibre-reinforced laminated composites in structural design is the ability to change the stiffness and strength properties of the laminate by designing the laminate stacking sequence in order to improve its performance. This procedure is typically referred to as laminate tailoring. In this work we experimentally observed mechanical properties of glass/epoxy laminate with different stacking sequences. We observe stacking sequences of epoxy resin L 285 MGS: (0/90)6x, 3x0/3x90, (0/90)6x, 3x0/3x90, 6x(0/90), 6x0. We confirmed our predictions that mechanical properties can be very drastically increased by different stacking sequences. During our research we determined tensile properties according to ISO 527-4 Test Standard.
This part of ISO 527 specifies the test conditions for the determination of the tensile properties of isotropic and orthotropic fibre-reinforced plastic composites.

KEY WORDS: mechanical properties, laminate composites, strength, stacking sequence

1. INTRODUCTION

The tensile test is the most widespread and the most studied mechanical test for composites. The popularity of this test method is explained mainly by the ease of processing and analysis of the test results. The characteristics obtained from tensile tests are used both for material specifications and for estimation of load-carrying capacity.

Strength of materials is always primary concern in tensile tests. Several researches have been carried out in order to characterize the composite materials. The variety of experimental techniques used to characterize the static mechanical properties of filament-wound composites and the practical pitfalls to be avoided and the data reduction procedures necessary to reduce the test data are discussed by Charles [1].

The scale and size effects in the strength characterization of composite materials are investigated by Sutherland et al, [2-5] the investigation was focused on the tensile and flexural strengths of glass/epoxy laminates. The work highlights the importance of fabrication factors and the distinguishing difference between scale effects and size effects.

2. MATERIAL AND SPECIMEN SPECIFICATION

At the first step we did tensile test on eight types of different laminate composites with various stacking sequences. We measured width and thickness of every sample on three parts, and then we calculated average values.

Investigated specimens were deformed by constant speed along the main axis to breaking, or by stress or by deformation which didn't achieve predetermined value. During test we measured stress sample and strain.

Selected eight types of laminate lay-ups were analysed under loading conditions. Table 1 summarises laminate type, material type of the investigated samples. Table 2 describes experimental results of mechanical properties of investigated laminate samples.

Tab. 1: Description of investigated glass/epoxy samples with stacking sequences and direction of tensile loading

Samples	**Type of laminate**	**Type of fabric**	**Matrix**	**Composition of layers**	**Direction of tensile loading**
1A	glass/epoxy	220g/m^2-Interglas unidirectional	Epoxy resin L285 MGS	(0°/90°) 6x alternate stowing	90°
1B	glass/epoxy	220g/m^2-Interglas unidirectional	Epoxy resin L285 MGS	3x0°/3x90°	90°
1C	glass/epoxy	220g/m^2-Interglas unidirectional	Epoxy resin L285 MGS	(0°/90°) 6x alternate stowing	45°
1D	glass/epoxy	220g/m^2-Interglas unidirectional	Epoxy resin L285 MGS	3x0°/3x90°	45°
1E	glass/epoxy	220g/m^2-fabric plain weave	Epoxy resin L285 MGS	6x(0°/90°)	90°
1F	glass/epoxy	350g/m^2-fabric twilled	Epoxy resin L285 MGS	6x(0°/90°)	90°
1G	glass/epoxy	220g/m^2-Interglas 92145 unidirectional	Epoxy resin L285 MGS	6x0°	0°
1H	glass/epoxy	220g/m^2-Interglas unidirectional	Epoxy resin L285 MGS	6x0°	90°

The characterization of the material in this paper is restricted to static behaviour and properties in room temperature to find the elastic properties of the glass fibre/epoxy composite laminate. Moreover it studies the failure modes for different winding angles.

Stacking sequences	**Tensile strength δ [MPa]**	**Tensile strain ε [%]**	**Direction of strain**
6x(0°/90°) alternate stowing	$\overline{\sigma} = 219.85$	$\overline{\varepsilon} = 4.29$	90°

Fig. 1: Photograph of the failed tensile test specimen 1A with experimental values

Stacking sequences	**Tensile strength δ [MPa]**	**Tensile strain ε [%]**	**Direction of strain**
3x0°/3x90°	$\overline{\sigma} = 282.81$	$\overline{\varepsilon} = 5.01$	90°

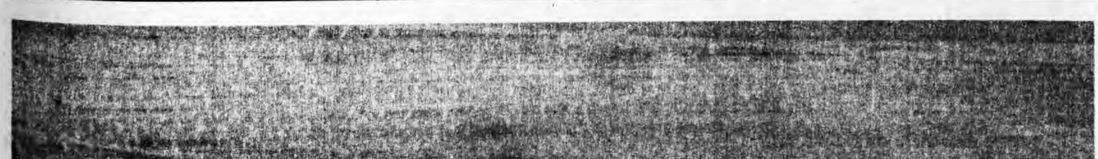

Fig. 2: Photograph of the failed tensile test specimen 1B with experimental values

Stacking sequences	Tensile strength δ [MPa]	Tensile strain ε [%]	Direction of strain
6x(0°/90°) alternate stowing	$\overline{\sigma} = 93.55$	$\overline{\varepsilon} = 9.41$	45°

Fig. 3: Photograph of the failed tensile test specimen 1C with experimental values

Stacking sequences	Tensile strength δ [MPa]	Tensile strain ε [%]	Direction of strain
3x0°/3x90°	$\overline{\sigma} = 79.22$	$\overline{\varepsilon} = 6.40$	45°

Fig. 4: Photograph of the failed tensile test specimen 1D with experimental values

Stacking sequences	Tensile strength δ [MPa]	Tensile strain ε [%]	Direction of strain
6x0°	$\overline{\sigma} = 45.77$	$\overline{\varepsilon} = 2.44$	90°

Fig. 5: Photograph of the failed tensile test specimen 1H with experimental values

Tab. 2: Values obtained from tensile test according to EN ISO 527-4

Sample	Thickness [mm]	Width [mm]	Gauge length L_0 [mm]	Strength F_m [N]	Tensile strength δ [MPa]	Tensile strain ε [%]
1A	1.34	25.25	170	7416.87	219.85	4.29
1B	1.37	25.61	170	9801.80	282.81	5.01
1C	1.23	25.03	170	2863.74	93.07	9.41
1D	1.07	24.87	170	2073.73	78.37	6.27
1E	1.26	25.03	170	11727.32	371.08	5.48
1F	1.23	25.05	170	10584.4	345.63	5.11
1G	1.07	24.78	170	13836.4	519.34	5.17
1H	1.11	25.97	170	1322	45.77	2.44

A photograph of the tension specimens after failure is shown in Figures 1, 2, 3, 4, 5. The failures on the specimens are sudden and catastrophic, and confined to the vicinity of the break. From surface inspection of the failed coupons, it is noticed that fracture tends to follow the path that frees from the fibre in the direction of laminated angles.

Glass-epoxy composites are available as unidirectional reinforced plies (bundles or roving), chopped reinforced epoxy (usually reasonably isotropic in the plane) or twisted yarns may be cross woven to produce a fabric. Glass-epoxy materials are commercially available as: unidirectional prepreg tape, cross-woven prepreg fabric, spools of roving material for winding, continuous filament for filament winding, cured laminates, chopped fibres. [6,7]

One can purchase a particular glass filament, roving, yarn or fabric and have it prepreged with a particular resin at a specified fibre content, etc.

Many different types of composite materials are available. To make the exercise manageable, consideration was limited to continuous-fibre-reinforced thermosetting plastics. Taking into consideration the availability of suitably extensive experimental data for laminates, important and widely used class of fibre are E-glass and one group of resin systems (epoxy resins) were selected for the exercise.

3. CONCLUSIONS

The maximum tensile load for glass fibre/epoxy composite was improved in case of 0° fibre orientation angle to a higher value than that of 90° fibre orientation angle and the specimens show a brittle fracture of the matrix and fibre breaks gradually.

Tensile test shows that the load increased to the maximum value and then dropped suddenly as a brittle fracture for composite materials at angles 0°, 90°.

In this paper we present lamina properties, lay-up configurations and loading conditions for a range of fibre-reinforced composite laminates.

4. REFERENCES

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